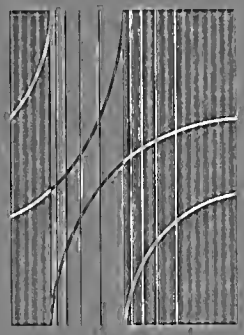

Joint Transportation Research Program

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Final Report

AUTOMATING FIELD DATA COLLECTION IN MAINTENANCE OPERATIONS

Bob McCullouch

August 21, 1997

Indiana Department of Transportation

Purdue University

Final Report

Automating Field Data Collection in Maintenance Operations

by

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School of Civil Engineering

Joint Transportation Research Program
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Conducted in cooperation with the

Indiana Department of Transportation

and

Federal Highway Administration
U.S. Department of Transportation

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Purdue University
School of Civil Engineering
West Lafayette, Indiana
August 21, 1997

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16. Abstract

Field data collection and management in DOT organizations requires a considerable amount of resources in the form of personnel and management systems. Recent studies performed by the researcher revealed that an average of 30-50% of some field supervisory personnel's time is spent on processing field data paperwork. This is a considerable amount of time spent on an undesirable task and is taking these employees away from more important job duties. This project automated two maintenance field data collection functions. One was a Crew Day Card, which is a card used by a maintenance crew to document the activity performed. Information on labor, equipment, material, and the task is recorded. The second application was Sign Inventory, which is used to perform inventory on roadside signs. These applications were placed on a pen computer and tested in the field. This report describes these two electronic applications and documents the lessons learned form the field.

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Introduction

One of the last frontiers in data management is recording and managing data collected in the field at the jobsite either in the construction or maintenance phase. Previous studies(INDOT and BMW Constructors) (McCullouch)revealed that on the average between 30%-50% of field supervisory personnel is spent recording and analyzing field generated data. This is an excessive amount of time spent on an undesirable task.

This reality combined with the fact that INDOT is doing more with less personnel resources is creating challenges for employees. Computer technology can provide solutions. Because of this potential promise this project was performed. This report describes what was tried, learned, and tested. Findings from this project can serve as a departure point for INDOT into the automation of field data acquisition for construction and maintenance operations.

Problem Statement

Managing the maintenance of Indiana's transportation system requires documenting activities, inventorying system components and features, and tracking costs. Repairing and patching failed roadway components; maintaining system features such as signs, signals, lighting, roadway painting, and raised pavement markers; tracking herbicide treatment and mowing activities; safety inspections; lighting inspections; are some of the main activities in the maintenance management operation. These activities require detailed site documentation which is entered into a computerized maintenance management system.

As the Department moves toward a performance-based quality approach on new construction; it becomes very important to record and document the performance of these systems over their life. To do this adequately will require more effort in data

collection, storage and analysis.

Equally important is maintaining a current accurate inventory on roadside system features. This inventory will track a considerable number of items and their condition upon which budgets, resources and activities can be planned.

Because the Department is having to do more with less or constant resources is another factor favoring this type of data management process. This creates an environment for the Department maintenance personnel to seek out new methods and technologies in order to carry out the functions of the Department adequately .

Current computer technologies can provide assistance to maintenance personnel in the field generated data management process. One technology that is being planned to acquire construction field data is pen computers. This same technology can be applied to maintenance activities and automate field data collection and reduce the effort in managing this information.

Project Objectives

The main objective is to demonstrate the utilization of pen computer technology into maintenance operations. Pen computers are successfully being utilized in other industries to collect and analyze data. With pen computers, data is entered with a pen device. The user has the option of writing or drawing on the screen, selecting input values from pop-up lists, or using pop-up keyboard and/or keypad for entering data. Almost anything that can be recorded on a paper form can be recorded onto an electronic form. Once the information is recorded in electronic form it can be transferred into the maintenance management system, eliminating the task of keypunching data from the paper form into a computer, which in some cases requires several hours daily.

An ad-hoc committee was formed and met several times to identify application candidates. Members of this committee were: Tommy Nantung(Research); Larry Rust, Jerry Heistand, Larry Goode, Chris McFall, Lewis Hartman (Operations Support); Dale Copeland(Information Services); Troy Boyd (LaPorte District); Mike Rausch (Fort Wayne District); and Bob McCullouch(Purdue). At one meeting pen computer applications were demonstrated by Troy Boyd and Bob McCullouch; and Tommy Nantung described the paint inspection application. Hardware and software options were also discussed. After reviewing the technology capability the committee narrowed the list of potential applications down to two applications.

The first application is the **Sign Repair/Inventory** process. For this application, automation capabilities for data collection were developed. The second application is to develop an electronic **Crew Day Card** for traffic crews. For both applications prototype projects were performed in the field with the corresponding feedback used to develop the field version.

Project Activities

The following sequence of activities guided the development of each application.

1. Determine hardware and software needs and purchase.
2. Identify data requirements and develop electronic forms.
3. Investigate interface into Maintenance Management Computer System.
4. Coordinate design and data needs with Information Services.
5. Test hardware and application in field and revise per field comments.
6. Modify application and release to field crews for field prototyping.
7. Take field results and develop field version and implementation plan.

For the **Sign Inventory/Repair** application a Global Positioning System(GPS)

device was used to locate signs. This device is placed in the truck and can provide position coordinates for each sign. These coordinates are captured and transferred to the appropriate field on the electronic form.

Project Results

This section describes what was learned from the project and the applications developed.

Hardware and Software

A considerable effort was spent on researching hardware. One of the reasons was the budget we had($6000) for a pen device and a GPS receiver. We wanted to be confident on what we invested in. After a review period of approximately a month the results were reported back to the Study Advisory committee. The hardware options separated into three size categories; notebook or clipboard, slate or handheld, and Personal Data Assistants (PDA).

In a Study Advisory committee meeting these three size options were described. The committee felt there would be some value to evaluate all three because it would provide a realistic assessment of which type fits best for INDOT. Because it would be economically impossible to obtain all three within our project budget, it was suggested to lease or rent the units during the evaluation period. Two vendors were contacted about this possibility. The two vendors(Norand and Symbol) agreed to participate by either leasing or loaning some of their equipment. A reconditioned PDA was purchased at a very reasonable price(<$500) from Casio, their Zoomer product. Pictures of the equipment obtained are shown next.

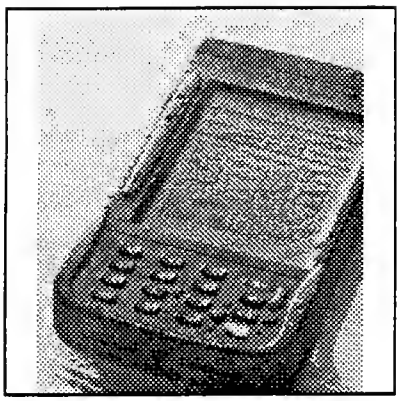


Figure 1 - Norand Handheld

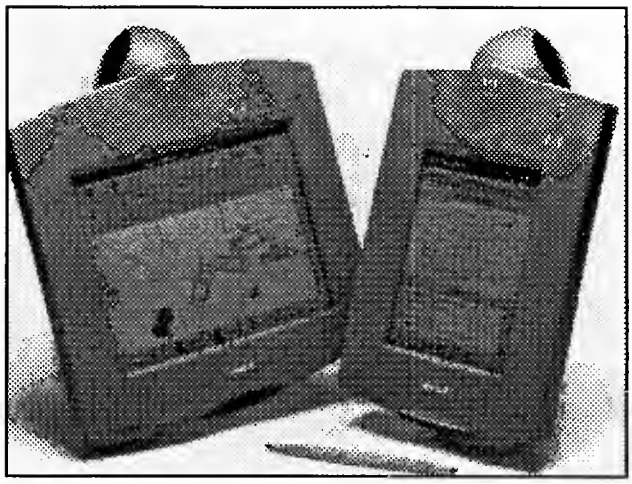


Figure 2 - Symbol Handhelds

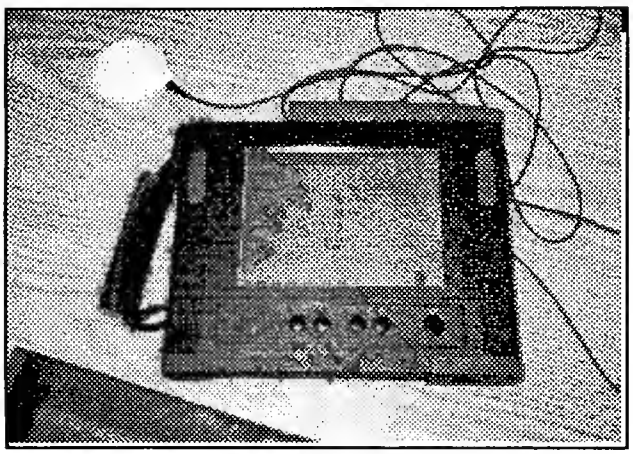


Figure 3 - Norand Notebook with GPS

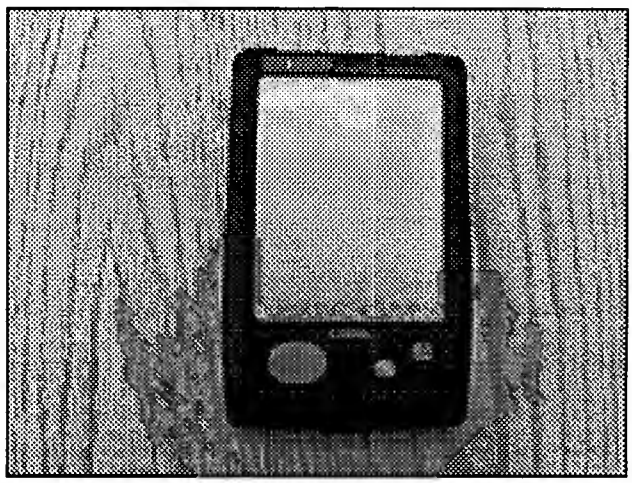


Figure 4 - Casio PDA

Because each device type has a different display size and configuration the applications forms had to be configured accordingly. This required a unique version for each device.

The PDA, Casio Zoomer, is a small hand held unit at a very reasonable price. Most PDAs cost less than $1000 which makes them attractive. During the project the PDA device went through a significant metamorphosis in operating system

environment. At the start of the project the operating system varied with the device. The Zoomer uses the GEOS operating system. A major problem with these types of operating systems was they could not run "windows" applications. Development software had to be purchased to run specifically on these devices. The SAC did not want to go this way. The approach taken was to develop applications that were not hardware dependent. At the end of the project Microsoft had released a new operating system for PDAs named Windows CE. With this operating system, Windows desktop applications could be ported in and run.

After the Casio Zoomer was obtained the applications were tried. In order to run them another piece of software had to be obtained named HOPE by Mobile Computing Systems. Several problems are inherent with this software. The applications can run after making some major adjustments. The one problem that could not be solved was the inability to use database files or tables for data input. This inability really destroys this option because data entry through popup lists can only be done by hardcoding the lists. Windows CE has the similar problem, the inability to use a data control for data entry. Windows CE applications are limited to spreadsheets, wordprocessing, calendar activities, etc. It currently is not suited well for data collection applications using electronic forms.

The determining factor in hardware selection was operator ease. Two hardware characteristics determine this. One is the pen response and the second is screen size and configuration. How the application responds when the pen interacts with the screen is very important. The screen size and how the forms are arranged is equally important. These two factors should be seriously evaluated because they determine the application ease of use. The Norand 6600 unit was chosen for these two reasons. Another factor to consider when selecting is durability. Most pen devices have been ruggedized for field applications.

After field tests were performed in the Fort Wayne District another hardware feature became evident. That is the process or procedure to transfer collected data from the field device to another computer in the office. For most pen devices this can be accomplished through a cable hookup or by transferring data through a PC card. The cable hookup requires data transfer software and physically attaching the machines through a data transfer cable. Data transfer problems are not uncommon which can cause this step to require more time tieing up hardware and frustrating the user.

An easier and quicker option is to transfer the data on a disk. Collected data is saved to a disk and the disk is turned in for data transfer and another disk is picked up to save field data to. So this option requires 2 disks. Almost all pen devices do not have a floppy drive therefore this type of transfer can only be done with a PC storage card that goes into a PCMCIA slot. These storage cards are very expensive($200-$300) and for a desktop system to read one another hardware peripheral is required that costs $200-$300. These expenses make this option undesirable.

Hardware that have a floppy drive is preferred. For this reason a laptop maybe a serious option. A laptop that can run this type of application can be purchased for approximately $1000 and data transfer can be performed with a floppy disk. Data entry follows the same process but a mouse instead of a pen is used and the keyboard is not needed. This hardware option has one big question and that is durability.

User Acceptance

The applications have been field tested in the Fort Wayne District. Comments and suggestions from field users were incorporated into the applications. Overall the response has been favorable. The users have found the applications easy to use and like the data entry process. Some think it will save time at the data entry phase and

like the "smart" form features. Resistance to this technology approach for collecting data has been nonexistent.

User Manual

Instructions on how the applications work are found in the Appendix. Sample screens show how the applications appear and work.

Study Benefits

This project has provided significant experience and "know-how" for determining the usefulness of applying "pen computing" to the task of field data collection. It has helped to answer questions about what hardware is appropriate?; what approaches work best for collecting data with this technology?; and, what is the best way to transfer field data into current INDOT data management systems?

Feedback from field users indicate they are saving time in collecting data. Also, since most entry is selected from approved, accurate data; the data quality improves significantly. This eliminates or reduces significantly the questioning of what was recorded before it is entered into a computer management system.

Another important benefit of the system is "down-stream" effects. Once the information is recorded electronically, the processing effort becomes simpler. For example, information can be electronically transferred into other computer management systems. It will reduce the time significantly for entering this information into these systems from a couple hours to a few minutes daily.

Besides time savings, this technology can improve the quality and accuracy of data as well as the desire to collect it. One benefit experienced in other pen data

collection applications is that data quality always improves. Less mistakes are made in recording and mistakes made during the transcription process are eliminated. Currently some roadside system features do not have an accurate up-to-date inventory. A major reason is the monumental effort and time required. Through this technology a tool can be used that will encourage and enhance the effort.

Implementation

Feedback from the Fort Wayne District indicates that field personnel are very receptive and interested in this type of tool. User acceptance is strong and the use of electronic forms is popular. Based on these results a statewide implementation project is being proposed. This project proposes to add a signal inventory application to the current two and try all out in the field. The project will also evaluate feature management software and develop a link into it from the field collection applications. Another link into INDOT's GIS system to display the features and their attributes graphically will be considered.

References

McCullouch, B.G. and Gunn, Paul (1993). "Construction Field Data Acquisition with Pen-Based Computers," Journal of Construction Engineering and Management, ASCE, 119(2), 374-384.

Appendix

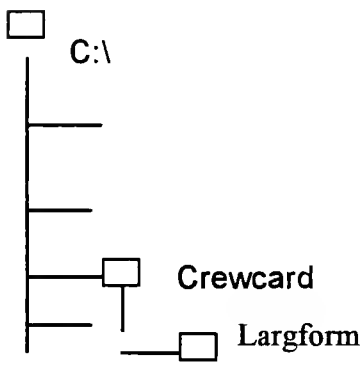
Installation and User Instructions

Setup Instructions

These instructions are to be used to install the **No GPS** application on another computer system. You will find three(3) disks that contain the application files. Files on these disks will be copied into directories located on the hard drive of your computer. The hard drive must be the drive letter **C**.

Directory Setup

On the C: drive create the directory **Crewcard** that has a directory named **Largform**. The directory structure should look like:



File Copy

Take Diskette #1 and copy files into the **Largform** subdirectory.

Diskettes #2 and #3 contain the .dll files and the Truegrid.vbx needed to run the application. Copy files on these two diskettes into the Windows\System directory. The required dlls and vbx files are:

Btrv110.dll

Msafinx.dll

Msaes110.dll

Msajt110.dll

Pdx110.dll

Vbdb300.dll

Vbrun300.dll

Ver.dll

Xbs110.dll

TrueGrid.vbx

For the GPS version two additional dlls are needed: Ctl3d.dll and Tgpsdll.dll. Also the file wmobile.exe is required. It will be placed in the directory Wmobile4. These files are provided on diskette #4. Copy the Crewcard.ini file located in the Largform directory into the Windows directory.

Icon Setup

The application has to be run from an icon on Program Manager(Windows 3.x) or Desktop(Windows 95). The following is for the Windows 3.x version.

On Program Manager select **File** then **New** and then select **Program Item**. The below dialog box(Figure 5) will appear on the screen.

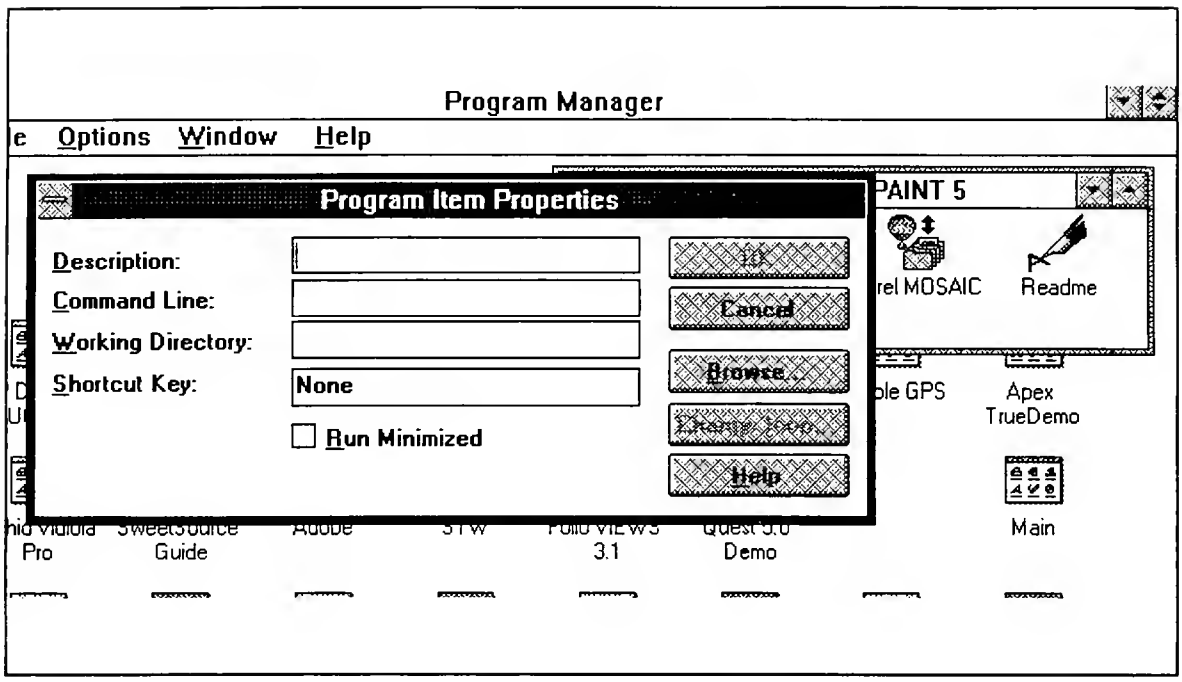


Figure 5- Application Shortcut Properties

Fill in values for the Description, Command Line, and Working Directory. Description is the name that will appear beneath the icon. The Command Line should read:

C:\crewcard\largform\crewcard.exe /nogps

space

Working Directory is C:\Crewcard\Largform. You change the icon by browsing and getting the INDOT icon located in the Largform directory.

For the GPS option, leave off the "/nogps" part of the command line. This part of the command line acts as a switch turning on and off GPS.

User Instructions

The below screen(Figure 6) appears when the Application icon is double clicked or tapped.

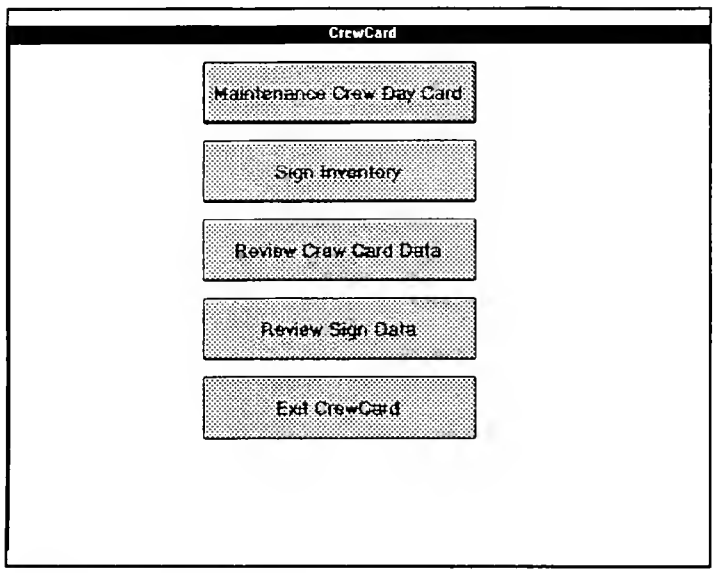


Figure 6 - Main Menu

On the above screen the user has five choices: Maintenance Crew Day Card; Sign Inventory; Review Crew Card Data; Review Sign Data; and Exit Crew Card. The review options simply allow the viewing of collected data for either application. The user can make changes to the data on these screens through the keyboard.

A click on the Maintenance Crew Day Card button opens the first form which is shown in Figure 7.

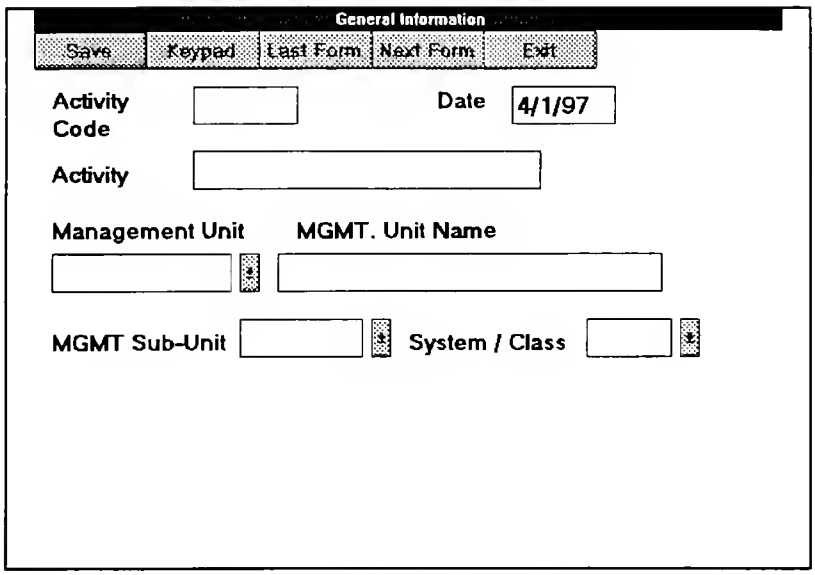


Figure 7- Crew Day Card Form 1

Data input is from either pop-up lists or pop-up keyboard or keypad. From the lists the user can scroll to search and select from the values shown. If to the right of the input box there is a gray box with a down arrow, a list will appear by clicking or tapping on the arrow. If this box is missing then the user should click inside the box and either a pop-up list, keyboard, or keypad will appear for data entry. On the above screen two data entry boxes have been selected as shown on the next figure. The first one, Activity Code, when the user clicks inside the box the scrollable list appears. When the user clicks on the arrow button to the right of Management Unit then the drop-down list appears as shown below in Figure 8. Selecting values in these boxes will cause values to fill in the Activity box and the Management Unit Name box. This was referred to as a "smart form" earlier in this report; when selecting one value triggers the filling in of other boxes. So in some cases the user selects one data entry value and others are filled on the form. This can save input time while eliminating entry errors.

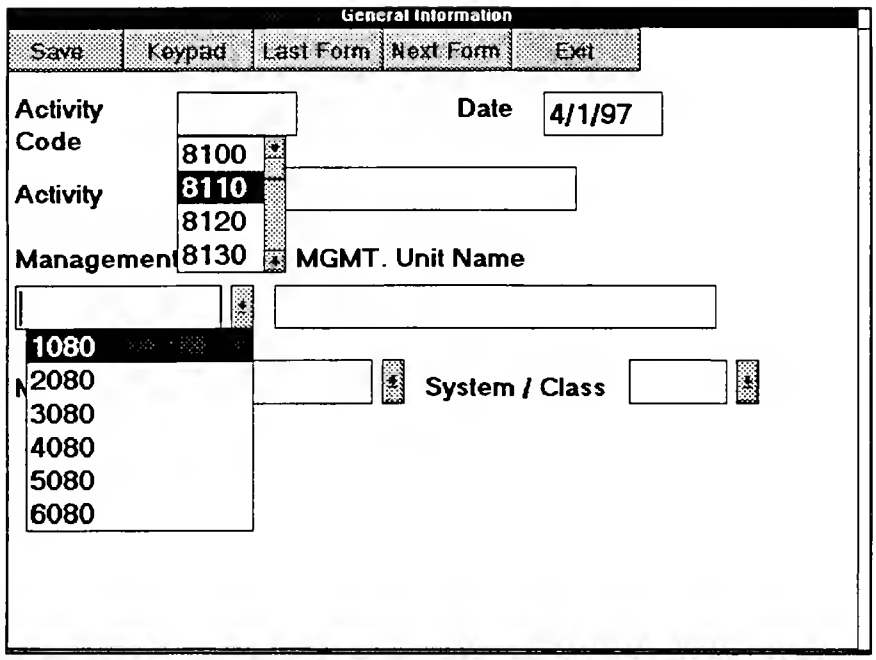


Figure 8 - Pop-up and Drop-down list

Pop-up keypads and/or keyboards are used for data entry when data cannot be selected from lists. In the design phase, user handwriting was considered as a data entry technique. Using this approach the user prints on the form with the pen. The pop-up keypad and keyboard option was chosen over this method for two reasons. One in handwriting recognition the characters have to be formed using a certain gesture pattern for the machine to recognize it and convert it to a ASCII character. This would require each user to learn the gesture patterns. The second reason is that character recognition is at best only 95-98% accurate after correctly forming a character. So these two factors together will frustrate the user and increase the likelihood of user rejection. This is why the popup keypad and keyboard approach was taken. Figure 9 shows a popup keypad that is used for entering equipment quantity.

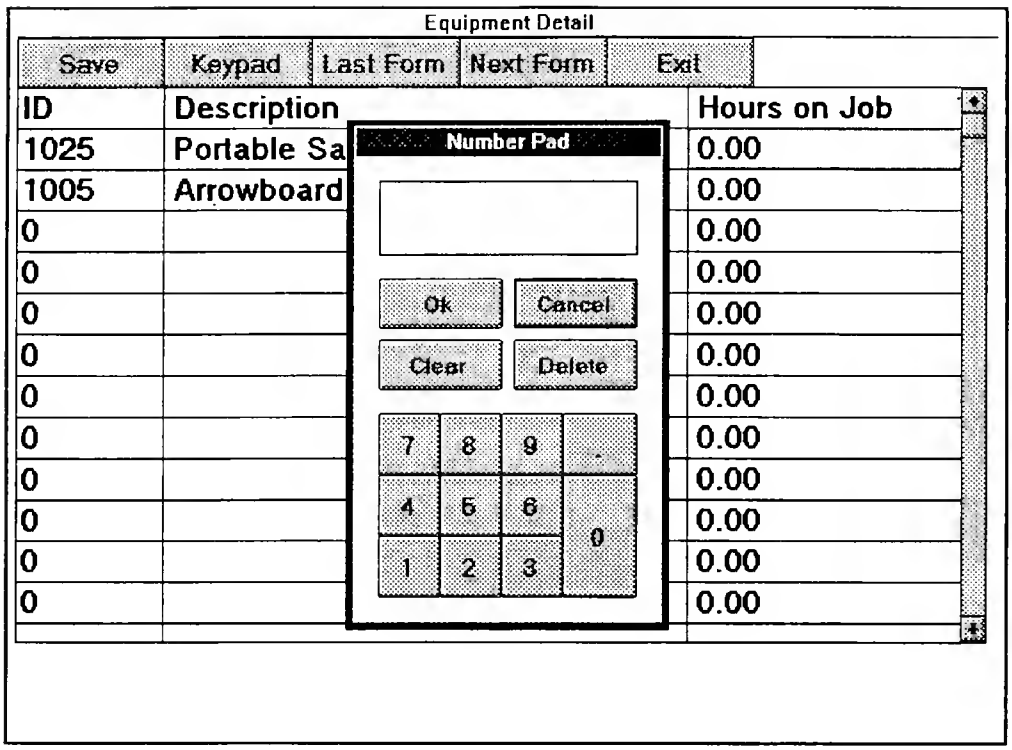


Figure 9 - Popup Keypad

On the Accomplishment Form the unit values are prefilled. This comes from the activity code selected which has a corresponding unit value. The Location Code values are dependent on the Location Type value therefore the user must select a Type value first. Location Code values are generated from Location Type so the user needs to allow a few seconds(<10) for the generated list to appear.

At the top of each form are buttons used to navigate between forms, Last Form and Next Form; save the collected data to a text file(Save); and exit the application, Exit. If the forms are incomplete then the user will be prompted to either enter information or ignore that particular input field. The Keypad button is currently inactive.

Looking at Figure 6 again, the second button on the menu is Sign Inventory. Click this

button and the screen looks like Figure 10.

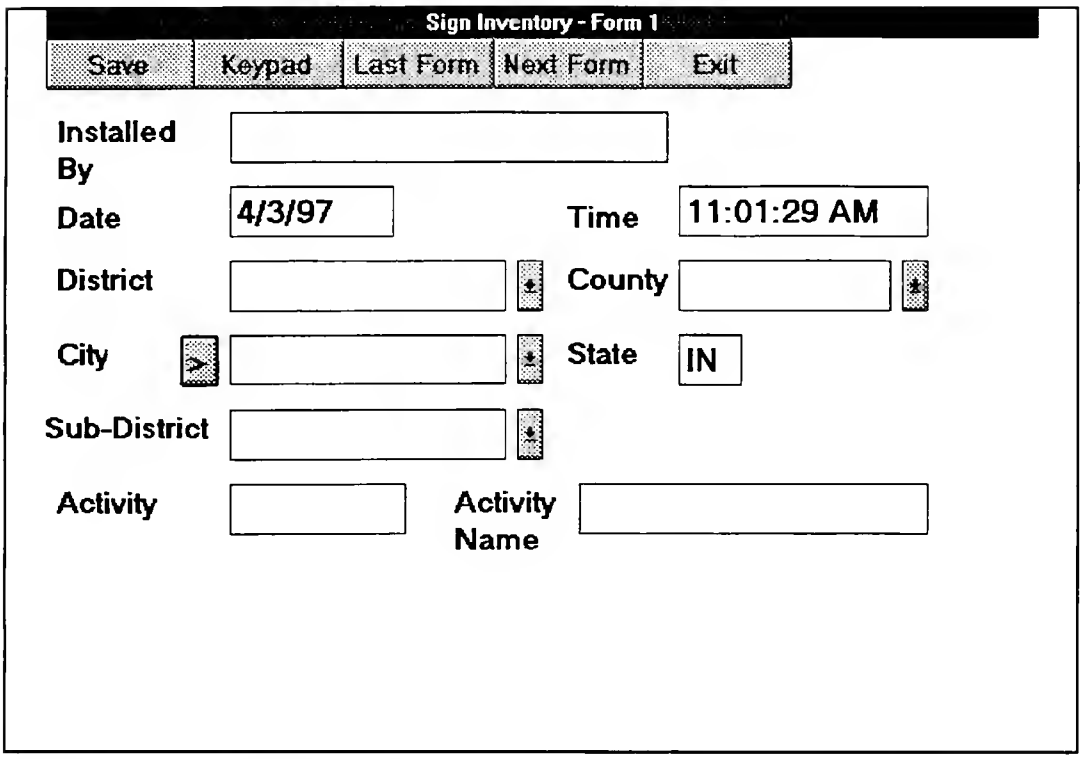


Figure 10 - Sign Inventory Screen

Data input in this application is performed the same way through lists and popup keyboard and keypad. Notice next to the City box is a right pointing arrow button. This pulls up a keyboard that can be used to enter city name if a list is not available. The rest of the forms are filled out in similar fashion. On the last form(shown in figure 11) is a button that says USE GPS FOR NAVIGATIONAL DATA. Clicking it will pull in the values for Longitude and Latitude. The GPS card requires some time to accurately locate three satellites required for positioning so if this button is clicked within 5 minutes after starting the application erroneous values may be produced. Accuracy is dependent on the type of card. A Trimble Gold card was used on this project which has differential correction making the accuracy tolerance $\pm$ 5 meters. Accuracy is dependent on the type of card.

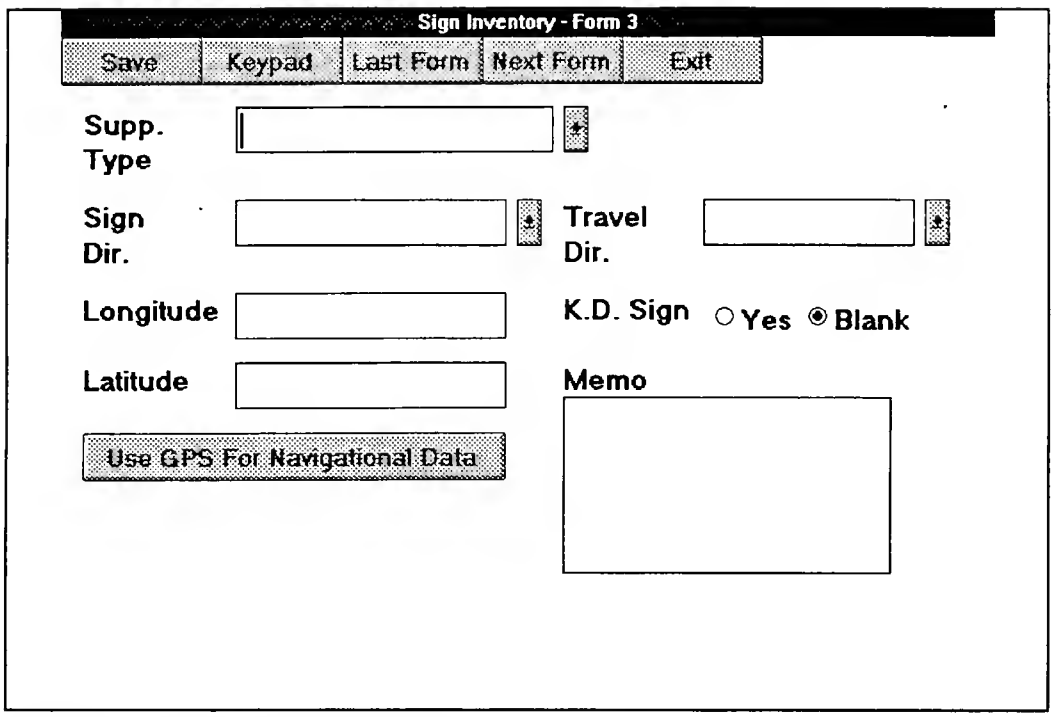


Figure 11 - Sign Inventory GPS data

On the main menu two selections are for reviewing the data collected in the Crew Day Card and Sign Inventory applications. Figure 12 shows the screen for the sign inventory data.

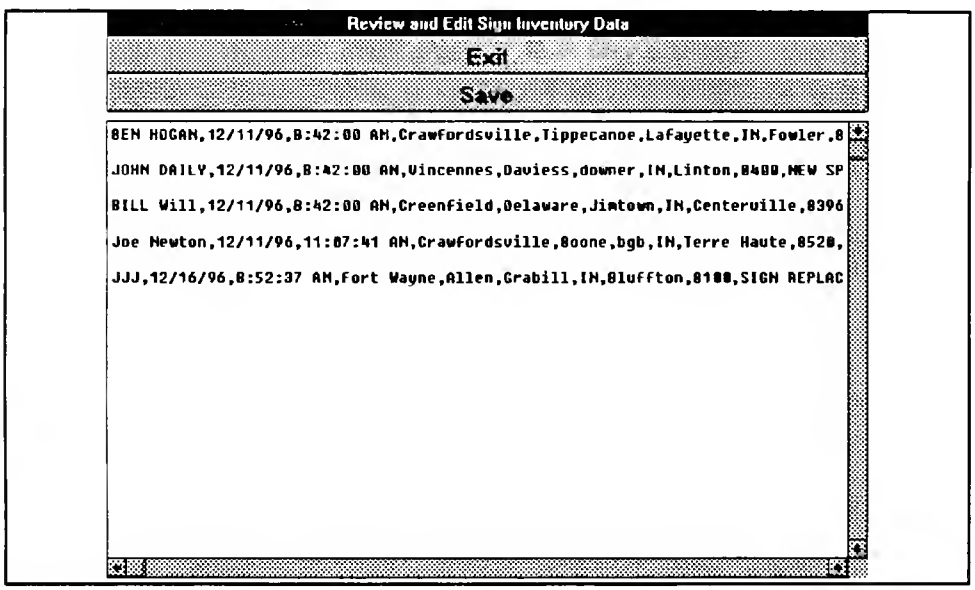


Figure 12- Review Form

The above screen shows sign inventory data . Each line is a data collection session. The collector can review and make changes from this screen by using a keyboard to do the editing. The crew card data appears differently because it is structured to load straight into the Maintenance Management System. Before the collected data is posted into this system it should be reviewed by a clerk for accuracy. This can be done by bringing the file into word processing software and viewing since the file is a text file. Once the clerk becomes accustomed to seeing the data structured this way then the review step should go quickly.